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## Granularity in the Magnetic Field Structure of M83

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### Introduction

We have recently reported VLA 20 cm continuum polarization observations of the bright, nearly face-on southern spiral galaxy M83 (NGC 5236) at a spatial resolution of 2 kpc (Sukumar and Allen 1989). The strongest linearly-polarized emission is found in two giant arcs, with typical lengths of about 30 kpc, which are situated roughly opposite each other in the dark outer regions of the galaxy at a radius of 12 kpc from the center. These regions of high polarized intensity (and hence highly-uniform magnetic field) do not coincide with any prominent spiral-arm tracers, in contrast to the expectations of simple models for the large-scale compression of magnetic field in density-wave shock fronts. From a comparison of our data with previous results at 6 cm, we concluded that the low polarization in the central regions of the galaxy is a result of disorder in the interstellar magnetic field. The most likely cause of this disorder is the greater star formation activity observed in the inner parts of the galaxy.

The intrinsic direction of the magnetic field in the outer parts of the galaxy has also recently been determined on a length scale of 6.5 kpc from a comparison of the VLA 20 cm results with 6.3 cm observations obtained earlier with the Effelsberg telescope (Sukumar *et al.* 1989). There is very little Faraday rotation in the regions of the highly-polarized arcs of emission. The magnetic field in these polarized arcs is parallel to the general spiral arm structure seen in the usual optical tracers (dust, H II regions) in the bright inner parts of the galaxy disk. The maximum observed polarization at 2 kpc resolution is about 50%.

### Higher-Resolution Observations

The VLA "D" configuration observations described in Sukumar and Allen (1989) have been supplemented with additional "B" and "C" configuration data. A total of 17.8 hours of observations were made between 1987 September and 1988 August in two 25 MHz frequency bands centered around 1452 and 1502 MHz. The combined spatial frequency coverage of the observations provided a high resolution of up to 10" as well as remaining sensitive to structures as large as 30'.

A detailed comparison of the individual interferometer visibilities as a function of time revealed numerous differences between the signals recorded at the two adjacent frequency bands. These differences were traced to low-level intermittent correlator defects which, while they usually have little effect on the total intensity, are a serious limitation to the accurate determination of polarization. We found it necessary to reject about 20% of the data which showed inconsistencies between the two adjacent frequency bands. About 25 hours of cpu time on an Alliant FX-8 were required for this part of the data processing, which included plotting and flagging the visibility data, and initial map construction and self-calibration of the observations from each configuration separately. The NRAO AIPS software system was used for this work on the Alliant.

The final visibility data was constructed into images of the total and linearly-polarized radio emission at several different angular resolutions using the WERONG software package available on the CRAY X-MP/48 computer at the National Center for Supercomputing Applications in Illinois. Approximately one million visibility points were included in the constructions, which took a total of 2.5 cpu hours on the CRAY for further self-calibration and CLEANing to faint levels. Figure 1 shows the results of one of these constructions; maps of the 20-cm continuum intensity (Figure 1a) and linear polarisation (Figure 1b) of M83 with  $10'' \times 10''$  resolution (FWHM) and  $3'' \times 3''$  pixels. These two images have been extracted from larger fields of sizes  $1024 \times 1024$  which were the final products of the construction. As an example, the total intensity map in Figure 1a required 2.5 million CLEAN iterations. The noise limit on the total intensity map in Figure 1a is  $60 \mu\text{Jy beam}^{-1}$ , and on the polarisation map in Figure 1b it is  $25 \mu\text{Jy beam}^{-1}$ . These maps are shown as contour diagrams with levels increasing by factors of  $2^{(N/2)}$ . In Figure 1b we have also shown the direction of maximum polarized intensity (the E field orientation) as vectors whose lengths are proportional to the intensity of the polarised emission. Assuming a distance of 8.9 Mpc to M83, the linear resolution in Figure 1 is 430 pc.

## Discussion

Figure 1b shows that the smooth arcs of polarised emission found by Sukumar and Allen at lower resolution break up into stringy lumps or "granules" which are often still not entirely resolved. These concentrations exhibit only a weak correlation with discrete features on the periphery of the total intensity map in Figure 1a. With the increase in linear resolution from 2 kpc to 0.43 kpc, the maximum degree of linear polarization observed in the arc regions has grown from 50% to 75%; this is close to the expected theoretical maximum in the limit of a completely-aligned magnetic field.

We conclude that Figure 1b is showing us the basic structure of the ordered component of the magnetic field in M83. *This ordered component of the magnetic field is intrinsically granular*, with regions of typically a few hundred parsec in size exhibiting essentially perfectly-ordered field, separated by regions of roughly the same size (or somewhat larger) where the degree of field alignment is not high. Another remarkable feature of Figure 1b is that *the magnetic field direction is similar in neighboring granules*, in spite of the existence of disordered field between them.

## Conclusions

A detailed discussion of these results is beyond the scope of this poster paper. However, while the large scale field morphology (cf. Sukumar and Allen 1989) may be adequately described by current models of galactic dynamos (e.g. Ruzmaikin *et al.* 1988), an explanation of the granular structure we have reported here will most likely require a discussion of the temporal and spatial behavior of instabilities in a multi-component magnetized interstellar medium. For further input to such models, the following features of the observations should be noted: The *direction* of the magnetic field is clearly tied to the mechanism responsible for the spiral structure in the galaxy, and; the *degree of order* of the magnetic field appears to be closely related to the turbulence in the interstellar gas.

Further analysis of these observations is in progress. We are particularly interested in the detailed correlation of the polarised emission with a number of other components, such as the total radio continuum emission, small-scale optically-visible features in the galaxy such as dust concentrations and small H II regions, and the distribution and degree of turbulence in H I, H  $\alpha$ , and CO.

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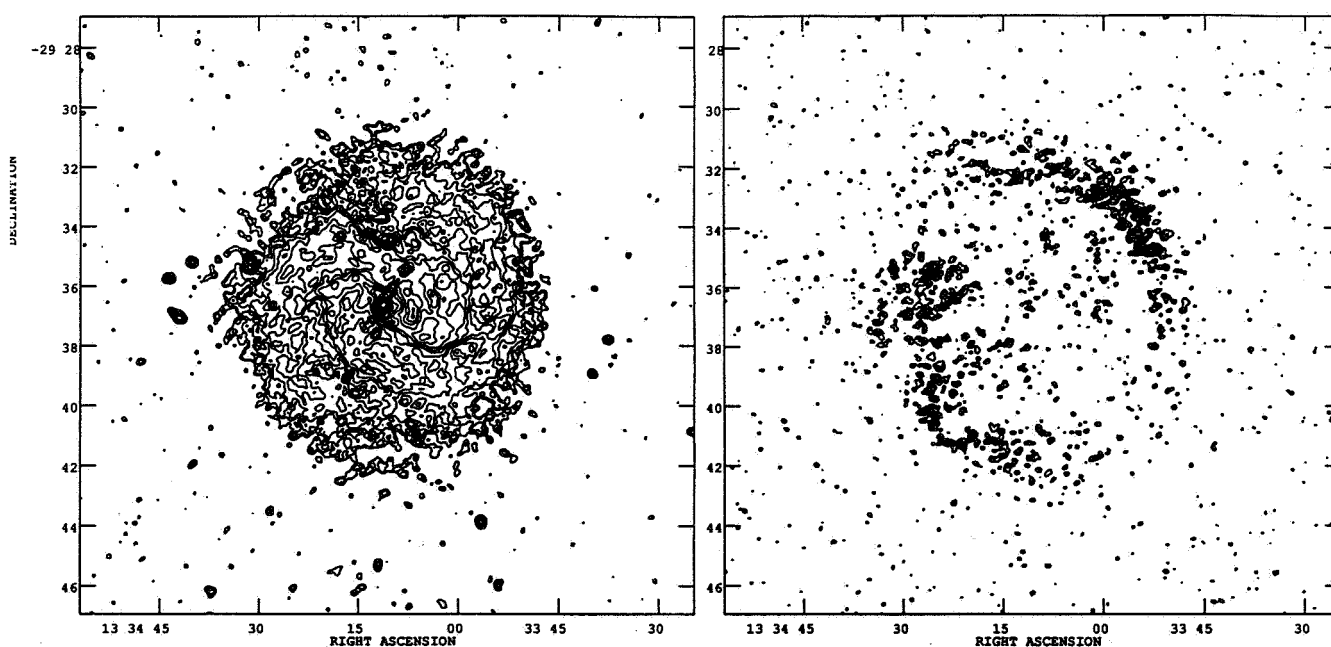


Figure 1a (left panel) Contour representation of the total radio continuum surface brightness of M83, observed with the VLA at 20 cm wavelength. Contours start at  $150 \mu\text{Jy beam}^{-1}$  and increase thereafter by a factor  $\sqrt{2}$ . The restoring beam width is  $10'' \times 10''$ , and the rms noise is  $60 \mu\text{Jy beam}^{-1}$ .

Figure 1b (right panel) Polarized brightness of M83. The parameters are as in Figure 1a, except that the contours start at  $80 \mu\text{Jy beam}^{-1}$  and the rms noise is  $25 \mu\text{Jy beam}^{-1}$ .